



National Aeronautics and
Space Administration
Marshall Space Flight Center



Rapid Prototyping of Biological Materials for In-Space Applications

NASA *In Situ* Fabrication and Repair (ISFR)

**Presented to 3rd International Symposium on Advanced Biomaterials/Biomechanics
on April 3 – 6, 2005**

Natalie C. Frazier

Morgan Research Corporation

ISFR Systems Engineer

Natalie.Frazier@msfc.nasa.gov



Marshall
Space Flight
Center

SSERO



ISAB³
April 3-6, 2005
Page 2

Presentation Outline

- Why is this technology needed?
- In-Situ Fabrication and Repair (ISFR) and In-Situ Resource Utilization (ISRU)
- Multi-Material Fabricator
- Medical Products
- Bioplotter
- Closing Remarks
- Additional Information





Marshall
Space Flight
Center

SSERO



ISAB²
April 3-6, 2000
Page 3

Why is This Technology Needed?

- President Bush's Exploration Initiative to return to the Moon and venture to Mars with manned missions
- Longer duration missions without near access to Earth will require increased maintainability of systems
- **Component degradation and failure is inevitable**
- The Space Architect has identified sparing as a principal issue for reducing the mass required for long duration exploration missions
- **It would not be practical to carry a complete spare parts and tools inventory, nor would an extensive collection of spares necessarily fulfill every emergency need**
- Fabrication of new tools *in situ* to cover unforeseen needs will significantly mitigate risk
- Fabrication equipment used for components, parts, and tools can be used for biological applications
- Humans living in reduced gravity and harsh environment for extended periods of time
- Additional potential for crew injuries
- As the distance between Mission location and Earth increases, risk increases



Marshall
Space Flight
Center

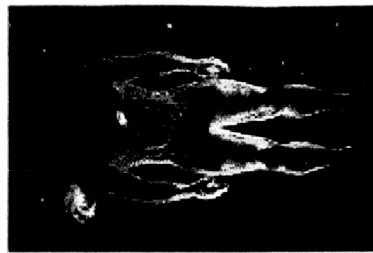
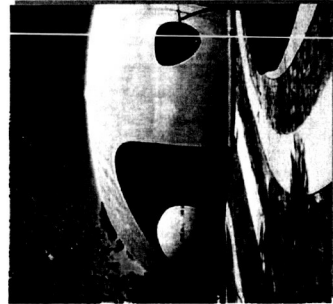
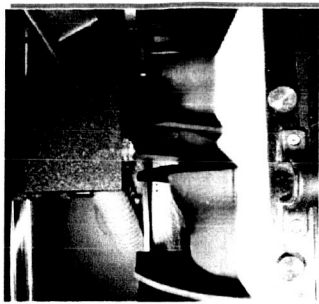
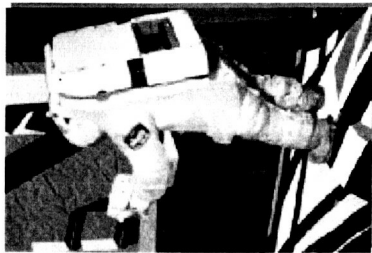
ISFR



ISAB²
April 3-6, 2000
Page 4

ISFR and ISRU

- In-Situ Fabrication and Repair (ISFR)
 - Fabrication Technologies
 - Medical Products
 - Bioplotter
 - Repair and NDE Technologies
 - Medical Products
 - Habitat Structures
- Baseline Concept for ISFR uses provisioned resources
- Utilize ISRU “mined and refined” capability as it matures
- In-Situ Resource Utilization (ISRU)
 - Maximize the use of natural resources through the extraction from and/or transformation of Lunar and Martian regoliths
 - Provide many of the needed ISFR feed-stocks for fabrication processes including
 - Silicon
 - Iron, aluminum, titanium
 - Glass/Ceramics
 - Recycling





Marshall
Space Flight
Center

SSLEO



ISAB²
April 3-6, 2003
Page 5

Multi-Material Fabricator

- Multi-Material Fabricator concept comprised of 2 – 3 racks; 1 rack approximately the size of a refrigerator
- Multiple technologies with various ranges of materials processing capability
- Evolving additive techniques for solid freeform fabrication (SFF) rapid prototyping, with focus on multi-material and direct manufacturing
- Wide range of techniques being considered in MSFC Trade Study such as Ultrasonic Object Consolidation (UOC), plasma spray, inkjet printing, and CNC Machining (subtractive technique)
- Feed Stock (e.g., powder, slurries, impregnated filaments, etc.)
- Material capabilities: metals, polymers, ceramics, composites, adhesives
- Key areas of consideration
 - Weight and volume
 - Power
 - Heat generation
 - Operating Environment
 - Reliability
 - Crew Operations

From: Materialise Today 2002, vol 3





Marshall
Space Flight
Center

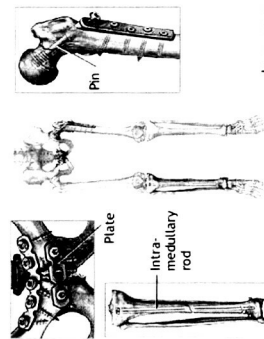
SSP



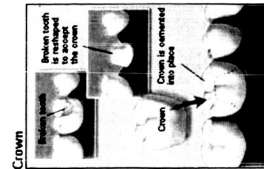
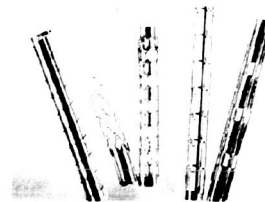
ISAB2
April 3-6, 2000
Page 6

Medical Products

- Target treatment of major and minor injuries
 - Triage for return to Earth
 - Treatment on-site
- Medical Product examples
 - Invasive: pins, plates, stints, catheters, sutures, surgical tools and dental instruments, adhesives for tissue binding and affixing implants
 - Non-invasive: casts, orthotics, tubes, syringes, gloves
 - Dental: fillings, crowns, bridges, dental cement
- Additional capabilities required
 - Sterilization capability
 - Libraries for medical procedures, dental procedures, and medical product specifications



adam.com



© 2000 W&A-BD Inc.



Marshall
Space Flight
Center

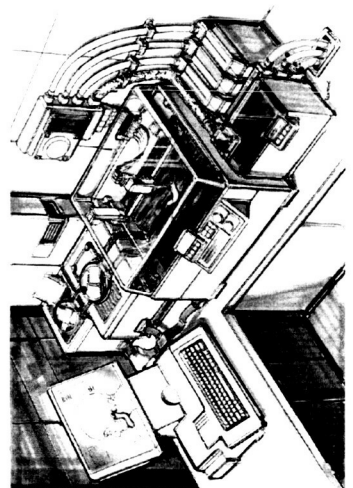
SSERO



ISAB²
April 3-6, 2000
Page 7

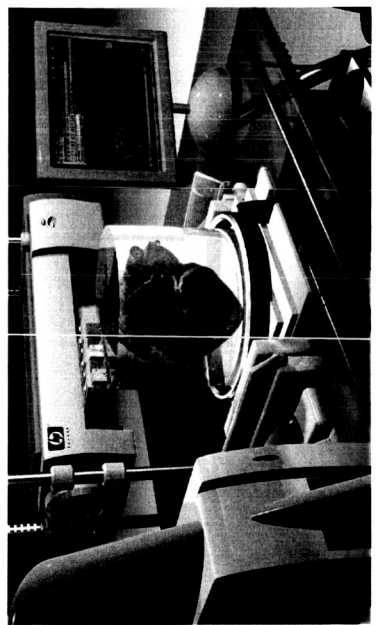
Bioplotter (Tissue Printing)

- Solid Freeform Fabrication (SFF)/Rapid Prototyping (RP) techniques for tissue printing
- Print viable human tissue on hydrogel scaffolds with high throughput, modified COTS inkjet printers
 - Aid in healing process
 - Replace damaged tissue
- Tissue Types
 - Near term capabilities - skin, bone, cartilage, connective tissue and blood vessels
 - Long range capabilities - other smooth muscle, skeletal muscle, and organs
- Potential development and demonstration of a Bioplotter for hypo-g and micro-g



Reference

Dr. Thomas Boland
Clemson University





Marshall
Space Flight
Center

SSERO



ISAB
April 3-6, 2000
Page 8

Closing Remarks

- Mimic terrestrial treatment capabilities of major and minor injuries in transit to and on extraterrestrial surfaces
 - Evaluate current technology and biomaterials for use in reduced gravity and harsh environment
 - Development of new biocompatible materials that can be made with refined Lunar (oxides, Ti) or Martian (oxides, carbon) Regolith
 - Development of new diagnostic equipment that is miniaturized, multi-functional, and can operate in reduced gravity
- Collaboration between NASA, Science Community, and Industry is essential to mission success





Marshall
Space Flight
Center

ISAB²



ISAB²
April 3-6, 2000
Page 9

Additional Information

- For more information on NASA's top Exploration concerns, visit the Bioastronautics Roadmap website at: <http://bioastroroadmap.nasa.gov/index.jsp>
- For more information concerning ISFR, visit the MSFC Exploration Science and Technology Division, In-Situ Fabrication and Repair website at: <http://est.msfc.nasa.gov/ISFR/>
- The Lunar Sourcebook: A User's Guide to the Moon, G.H. Heiken, D.T. Vaniman, & B.M. French, Eds., 1991, Cambridge University Press (available digitally through Lunar and Planetary Institute, <http://www.lpi.usra.edu>)
- Mining the Sky, J. S. Lewis, 1996, Perseus Books

